MARINE BIOTOXIN MONITORING PROGRAM

ANNUAL REPORT

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The Department of Health Services' Marine Biotoxin Monitoring Program would also like to acknowledge the dedicated work of the staff of the Department's Microbial Diseases Laboratory and the Food and Drug Laboratory for their efforts in conducting PSP assays and domoic acid analyses, respectively. Due to the unpredictable nature of marine biotoxin activity, the laboratories are often called upon to respond immediately to the influx of samples that result from these events. It is due to their efforts that we are able to provide rapid feedback to field samplers and the public.

Shellfish toxicity data is generated on a regular basis by the Department of Health Services' Marine Biotoxin Monitoring Program thanks to the continuing efforts of our program participants. Additionally, volunteers are collecting phytoplankton samples on an almost daily basis, providing near real-time observations of the occurrence of toxin producing species. As with all such endeavors, our success in protecting the public is due in large part to the numerous people who contribute their time and effort to collect samples at representative sites along the coast. The monthly listing of our program participants, provided in each monthly report, illustrates the diversity of groups and individuals that contribute to these efforts. The Department of Health Services expresses its sincere appreciation to our program participants for all of their efforts.

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INTRODUCTION

California has a long history of paralytic shellfish poisoning (PSP), dating back to the time of the coastal Native American tribes. According to Meyer (1928) it was a common procedure for the coastal Pomo tribe to place sentries to watch for luminescence in the waves, having apparently established a link between bioluminescence and mussel poisoning, both of which are caused by dinoflagellates in the phytoplankton. The long-standing concern of California's public health officials for protecting the public from PSP has been warranted, as there have been 542 reported illnesses including 39 deaths attributable to this toxin since 1927 (Price et al., 1991).

In the fall of 1991 another natural toxin was identified along the California coastline. Domoic acid, a neurotoxin of lower potency than the PSP toxins, has become of equal concern because the blooms of diatoms that produce this toxin have been of greater frequency and longer duration than most PSP events over the past 10 years. In addition, domoic acid has had dramatic impacts on marine mammal and seabird populations along the coast, raising the public's awareness of marine biotoxins in general.

Because PSP toxicity represents a serious ongoing public health threat that requires year-round attention, the California Department of Health Services (DHS) has implemented a prevention program that has traditionally been comprised of five basic elements: (1) a coastal shellfish monitoring program; (2) monitoring of commercial shellfish product; (3) an annual statewide quarantine on sport-harvested mussels (from May 1 through October 31); (4) mandatory reporting of disease cases; and (5) public information and education activities. In response to the occurrence of a new toxin, domoic acid, in 1991, DHS has added a sixth element to the Marine Biotoxin Monitoring Program: phytoplankton monitoring. This annual report describes the shellfish sampling element of the program for PSP toxins and domoic acid and the phytoplankton monitoring results during 2003. A summary is also provided for quarantine and health advisory activities.

Paralytic Shellfish Poisoning

PSP is an acute, sometimes fatal form of food poisoning that is associated with the consumption of bivalve molluscs that have fed on the toxin-producing dinoflagellate *Alexandrium catenella* (formerly *Protogonyaulax catenella* and *Gonyaulax catenella*). Eating shellfish that contain PSP toxins leads to an acute disturbance of the nervous system within a few minutes to a few hours. The PSP toxins are sodium channel blockers and thus inhibit neural transmission. Symptoms begin with tingling and numbness of the lips, tongue, and fingertips, followed by disturbed balance, lack of muscular coordination, slurred speech and difficulty in swallowing. In severe poisoning, complete muscular paralysis and death from asphyxiation can occur if breathing is not maintained by artificial means. There is no known antidote to the poison. Symptoms tend to resolve entirely in a day or two under proper medical care. Persons who suspect they or others are experiencing PSP symptoms should immediately seek medical treatment.

The type and severity of symptoms depends on the amount of toxic shellfish consumed as well as the specific toxicity of the shellfish. Price et al. (1991) summarize the range of toxin dose responses as follows: 200 to 500 micrograms (µg) will cause al least minor symptoms, 500 to 2000 µg will cause moderate to severe symptoms, and toxin concentrations greater than 2000 µg will produce serious to lethal effects. It should be noted that exceptions exist and serious health effects have also been documented at much lower concentrations (100 to 400 µg). The federal alert level for PSP toxicity is 80 µg per 100 grams (g) of shellfish tissue, and the detection limit for the PSP bioassay is approximately 40 µg/100 g.

Alexandrium is normally absent or constitutes a minor component of the marine phytoplankton community along the California coast. Under favorable environmental conditions this dinoflagellate may undergo periods of rapid population growth, frequently referred to as a “bloom”. The term “bloom” or “red tide” is misleading with respect to *Alexandrium* and the resultant PSP toxicity in shellfish. Visible blooms of *Alexandrium* are rarely seen along the California coast. Conversely, elevated levels of PSP toxins in shellfish can result from the presence of relatively low numbers of *Alexandrium* in the water.

The source of the dinoflagellates that provide the “seed” for such blooms is in question, but two likely scenarios are possible. First, resting cysts of *Alexandrium* in local sediments can, under favorable conditions, produce vegetative cells that can then reproduce both sexually and asexually, resulting in localized “hot spots” of PSP toxicity in shellfish. Second, this dinoflagellate may be transported in offshore warm water masses that can move onshore under certain environmental conditions. This advection process could potentially result in either a quick spike in PSP toxicity if the number of transported cells is high, or it may simply provide the cells necessary for a bloom to initiate. Regardless of the origins of the toxin-producing dinoflagellates, the general pattern has been for these blooms to be detected first along the open coast, occasionally followed by transport into bays and estuaries. The degree to which coastal phytoplankton blooms intrude into bays and estuaries is likely influenced in part by the orientation of the bay relative to coastal currents and by the extent of tidal mixing and transport that occurs inside the bay.

Domoic Acid

In October of 1991 the presence of another marine biotoxin was confirmed in California’s coastal waters. Domoic acid toxicity, which can result in the condition called amnesic shellfish poisoning (ASP), was identified as the cause of death in a large number of brown pelicans and Brandt’s cormorants in the Santa Cruz area of Monterey Bay. The birds had been feeding on schools of anchovies in the bay, which in turn had been feeding on a bloom of the diatom *Pseudo-nitzschia australis* (formerly *Nitzschia pseudoseriata*).

The only documented domoic acid event prior to 1991 was a serious episode in Prince Edward Island, eastern Canada, in 1987 in which three people died and over 100 people were made ill from the consumption of toxic mussels. Domoic acid is a neuroexcitatory amino acid that causes over-stimulation of certain nerves cells in the brain, with potentially permanent or fatal effects. Case studies of the Canadian episode indicated that the most common symptoms were gastrointestinal, followed by neurologic symptoms including headaches, loss of balance and/or dizziness, memory loss, varying degrees of confusion, disorientation, changes in the level of consciousness, and in some cases seizures (Teitelbaum, 1990; Perl et al., 1990).

Based on the rather small number of case histories available the following dose responses can be approximated while recognizing the overlap in ranges and symptoms: 27 to 75 µg/g may result in mild to moderate symptoms (gastrointestinal), 40 to 700 µg/g may result in moderate to severe neurologic symptoms, and domoic acid concentrations greater than 450 µg/g may result in severe neurologic symptoms and/or death.

Phytoplankton

There were no documented human health impacts from the 1991 Monterey Bay domoic acid episode, but the severity of the Canadian outbreak made it clear that continued monitoring for domoic acid would be necessary for public health protection. Because of the cost and time involved in running separate analyses for each toxin, in addition to the prospect that other known toxins may be present along the California coast, DHS began a volunteer-based phytoplankton monitoring program in 1993. The intent of this program was to develop a network of volunteer samplers and field observers that would allow the early detection of potentially toxigenic blooms. Early detection is key to mobilizing and focusing additional sampling and analytical resources for plankton, shellfish, and other species in the affected region. As a result of this volunteer effort DHS has been able to detect and track numerous harmful algal blooms, improving the capabilities for protecting the public health.

2003 SAMPLING EFFORT

Paralytic Shellfish Poisoning

Shellfish samples were collected at 83 different sites along the coast of California in 2003 (Figures 1a and 1b). Several commercial growing areas had multiple sites representing different harvest areas. There were 1086 shellfish samples collected statewide for PSP toxin assay during 2003. The greatest number of samples (388) was collected at sites in Marin County (Table 1), with commercial shellfish aquaculture companies providing approximately 96% of the total samples collected in this county. The majority of these (252) were contributed by Johnson Oyster Company in Drakes Estero, which samples four stations on at least a weekly basis. The large proportion of Marin County sites is a reflection of both the number of commercial growers and the frequency of occurrence of PSP toxicity in this region.

Commercial shellfish growers accounted for 66% of all samples collected in 2003, followed by coastal county health departments and various state agencies (14% each; Table 2). The latter category increased significantly from 2002 as a result of the involvement of several researchers and graduate students at U.C Santa Cruz, U.C. Santa Barbara, and U.C. San Diego. Several other program participants, including federal agencies and volunteers, provided valuable assistance by contributing their sampling effort in 2003, which exceeded efforts in 2002 (Table 3). As mentioned above, monitoring of the outer coast is a key element in California's marine biotoxin monitoring program because all toxic blooms to date have originated offshore or along the coast. Monitoring coastal shellfish resources can therefore provide an early warning of toxic conditions that may soon impact shellfish in bays and estuaries, which harbor the majority of commercial shellfish growers and recreational clam beds.

The majority of samples collected in 2003 consisted of mussels (71%), followed by cultured pacific oysters (28%; Table 4). Additional species of shellfish sampled for PSP toxin analysis in 2003 included rock scallops (*Crassadoma gigantea*), Washington clams (*Saxidomus nuttalli*), and Pismo clams (*Tivela stultorum*). The Marine Biotoxin Monitoring Program continues to use mussels as a primary indicator species for PSP toxins because of their ability to bioaccumulate these toxins at a faster rate that other bivalve species (Shumway, 1990). Differential uptake in mussels versus oysters during a major PSP event in 1991 was previously documented (California Department of Health Services, 1991).

Domoic Acid

There were 208 shellfish samples analyzed for domoic acid during 2003 compared to 359 samples analyzed the previous year (Table 5). The significant decrease in shellfish samples in 2003 was reflective of the monitoring program's adaptive response to the tracking of the temporal and spatial distribution of *Pseudo-nitzschia spp*., as described in the "Results" section. Samples from 55 different sampling sites, representing all but two coastal counties, were targeted for analysis as a result of observations from the volunteer monitoring network of high numbers of *Pseudo-nitzschia spp*. The greatest number of samples was submitted from Santa Barbara County (35), San Luis Obispo County (34), and Santa Cruz County (34).

Phytoplankton

There were 1097 phytoplankton samples collected during 2003, representing all coastal counties (Table 6). The greatest numbers of samples were collected in Marin (248), Los Angeles (164), San Luis Obispo (142), and Santa Barbara (122) counties. Samples were collected at 97 different sampling sites throughout these counties by 70 volunteers (Figures 1c and 1d). Several areas (e.g., commercial shellfish growing areas) had multiple sites that are not individually identified in the figure.

Of the 1097 phytoplankton samples collected in 2003, 543 (49%) contained at least one toxigenic species. Toxin-producing phytoplankton species were detected at 86 different sampling sites throughout all 15 coastal counties in 2003. The greatest number of samples containing toxin-producing species was collected in San Luis Obispo County (102), followed by Marin (84), Santa Barbara (59) and Los Angeles (57).

2003 RESULTS

Paralytic Shellfish Poisoning: Toxicity and *Alexandrium* Observations

The geographic distribution of PSP toxicity in 2003 was greater than observed in 2002, however the magnitude of toxicity was approximately the same (Figure 2). Measurable concentrations of PSP toxins were found in shellfish from the following coastal counties: Del Norte, Humboldt, Mendocino, Sonoma, Marin, San Francisco, San Mateo, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, and Los Angeles. PSP toxin concentrations at or above the alert level of 80 µg per 100 grams of shellfish meat were detected in 19 of the 206 positive samples (9%) from four counties: Humboldt (1), Mendocino (3), Sonoma (2), and Marin (13) counties.

The temporal distribution of PSP toxins in 2003 was atypical, with persistent low-level toxicity in several areas, but no pronounced toxin increases in early spring and mid-summer as usually occurs. The peak period of PSP toxicity in shellfish did not occur until late October, although high concentrations were detected in isolated areas in August (Figure 3). Low levels of PSP toxins were detected along the coast as early as February, and persisted through December in several areas (Table 7). *Alexandrium* was observed at sites in almost all coastal counties (Figures 4-6). The highest percent composition of *Alexandrium* was observed at sites in Marin, Santa Cruz, and Monterey counties. Detailed maps illustrating the weekly relative PSP toxin concentrations for each month, the monthly distribution and relative abundance of *Alexandrium* and *Pseudo-nitzschia*, and the monthly lists of program participants are provided in separate monthly reports. These reports are available at the following Internet site:

http://www.dhs.ca.gov/ps/ddwem/environmental/Shellfish/Shellfish.htm

Low numbers of *Alexandrium* were observed at sites along the Marin County coast in February and were associated with the first occurrence of PSP toxins in Drakes Estero. This pattern continued through mid-May, with PSP toxicity remaining below the alert level. Low levels of PSP toxins were also persistent in northern Monterey Bay at Santa Cruz throughout April and along the San Francisco coast (China Beach) in mid April and early May. Isolated occurrences of low concentrations of PSP toxins in mussels were also detected at sites in Los Angeles (February 26), Santa Barbara (March 19), and San Luis Obispo (April 27). By the beginning of June, *Alexandrium* had disappeared from the entire California coastline and PSP toxins were not detected at any location.

Small numbers of *Alexandrium* began reappearing at several Northern California sites in July. The first observation of this dinoflagellate occurred on July 1 at the Santa Cruz

Pier. By mid-month *Alexandrium* was observed at the Monterey Commercial Pier, offshore of Moss Landing, inside the Golden Gate at the Presidio Pier, and farther north inside Humboldt Bay. The first detection of PSP toxins since mid-May occurred on July 15 at the sentinel mussel site at the U.S. Coast Guard Pier in outer Humboldt Bay. Low levels of PSP toxins continued to be detected at this site, and farther inside Humboldt Bay at the Indian Island sentinel station, through mid-November. By mid-August the range of *Alexandrium* had expanded to include Del Norte County, and PSP toxins were being detected in shellfish from Santa Cruz through Trinidad Head in northern Humboldt County. During the last week of August the PSP toxin concentrations finally increased above the federal alert level at Moonstone Beach (81 µg) in Humboldt County and Fort Bragg (120 µg) in Mendocino County. By late September the PSP toxin concentration in mussels from Fort Bragg increased to 1600 µg. Elevated levels of these toxins were also detected along the Sonoma coast in September (108 µg on September 29) following an observed increase in the relative abundance of *Alexandrium* in this region.

The relative abundance of *Alexandrium* increased from Del Norte to San Luis Obispo counties in October. There was a significant increase in PSP toxin concentration in mussels at the Drakes Bay sentinel station, ranging from nondetectable on October 21 to 153 µg on October 30. Toxin levels also increased above the federal alert level inside Drakes Estero by the last week of October, with concentrations reaching 209 µg and 334 µg in mussels in the outer and mid Estero, respectively. The elevated level of PSP toxins detected along the Mendocino coast in September (1600 µg) declined but remained above the alert level at the end of October (147 µg). Low levels of PSP toxins were detected along the Sonoma coast at Salt Point State Park and inside Bodega Harbor. Low levels of PSP toxins were also detected farther south in San Mateo and Santa Cruz by the end of October and throughout the month in mussels from Morro Bay. Because of this pattern of increase in the distribution of PSP toxin concentrations and the detection of alert levels of these toxins, the annual mussel quarantine on sportharvested mussels was extended past the normal October 31 end date.

By November the relative abundance of *Alexandrium* began decreasing along the California coast, but this dinoflagellate remained present at a number of coastal locations in Marin, San Francisco, San Mateo, San Luis Obispo, and San Diego counties. There was a general decline in PSP toxin levels along the coast, with no toxicity detected south of Monterey Bay. Low concentrations of PSP toxins remained along the coast between Humboldt and Santa Cruz counties. The elevated level of PSP toxins detected along the Mendocino coast in September (1600 µg) and October (147 µg, October 27) finally decreased below the federal alert level in November. PSP toxicity briefly increased to 80 µg in Bodega Harbor (Sonoma County). Southward in Marin the elevated levels of PSP toxin concentration detected in October persisted through the first week of November. Low PSP toxin concentrations continued in Drakes Estero throughout the month and inside Tomales Bay through mid-month.

Alexandrium numbers continued to decrease throughout Northern California in December, but increased along the San Luis Obispo and Santa Barbara coast. Low concentrations of PSP toxins were detected throughout the month in Drakes Estero and

Pescadero Beach (San Mateo County). December marked the first month since July in which these toxins were absent from Humboldt Bay. PSP toxins were detected in mussels from the Cal Poly Pier during the last week of December.

Domoic Acid Toxicity and *Pseudo-nitzschia* Observations

The magnitude of domoic acid toxicity in 2003 was less than detected in 2002. Measurable concentrations of domoic acid were found in bivalve shellfish from the following coastal counties: Humboldt, Santa Cruz, San Luis Obispo, Santa Barbara, Los Angeles, Orange, and San Diego. In addition, domoic acid was detected in rock crab viscera from Sonoma and Marin counties and in spiny lobster viscera from Anacapa Island. Domoic acid concentrations at or above the alert level of 20 µg per gram (µg/g = ppm) of shellfish meat were detected in 13 of the 42 positive shellfish samples (9%) from four counties: Santa Cruz (5), Santa Barbara (5), and Los Angeles (3).

The temporal distribution of domoic acid in 2003 was characterized by a early spring bloom of *Pseudo-nitzschia*, with resultant high concentrations of toxin detected in shellfish from March through May (Figure 7). The first evidence of a bloom occurred in Santa Cruz in March, declining by April. As the Santa Cruz event disappeared the levels of *Pseudo-nitzschia* and domoic acid increased along the Santa Barbara coast, the latter exceeding the federal alert level by May 11 (Table 8). A separate fall event occurred as well, with greater concentrations detected in sardines than in nearshore shellfish.

Pseudo-nitzschia was observed at sites in all coastal counties (Figures 8-10). The highest percent composition of *Pseudo-nitzschia* (i.e., > 90%) was observed at sites in Del Norte, Humboldt, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, and Los Angeles counties. The percent composition data generated by the volunteer sampling network provides valuable information on trends in the phytoplankton community, allowing us to follow increases in the toxigenic species. This data alone can be misleading because it does not provide information on the density of cells present and therefore does not always provide a direct relationship to the probability of domoic acid being present in shellfish. The relationship to toxin concentration depends in part on the mass of toxin-producing cells present. In other words, *Pseudo-nitzschia* can be the dominant species present (>90% of the species present) but cell density can be quite low, in which case it is unlikely that domoic acid will be detected at significant levels. To compensate for the lack of cell density data in qualitative plankton net tows, a relative abundance index is determined for the toxigenic species that is based on the percent composition, the sampling effort (i.e., the total distance the net is towed through the water), and a volumetric estimate of the cell mass in the settled sample (Figures 11-13). Comparing the relative abundance index to the percent composition data can provide some insight into the overall magnitude of the bloom.

Low numbers of *Pseudo-nitzschia* were observed along most of the California coast in January and February. Volunteer sampling efforts in Santa Cruz and Monterey were instrumental in detecting an increase in the relative abundance of *Pseudo-nitzschia* by the first week of February (Figure 9). By February 9 *Pseudo-nitzschia* had become the dominant species of phytoplankton at the Santa Cruz Pier (80% relative abundance). This pattern persisted in March, with increasing cell densities also occurring farther north along the San Mateo and Marin coast. Low numbers of this diatom were also observed offshore near Catalina Island. The high concentrations of *Pseudo-nitzschia* observed by U.C. Santa Cruz at the Santa Cruz Pier coincided with increased numbers of this diatom in a volunteer's sample from the Monterey commercial pier. These observations prompted the analyses of shellfish samples for domoic acid. Elevated concentrations of domoic acid were detected in mussels from the Santa Cruz Pier on March 12 (32 ppm) and March 26 (68 ppm). A mussel sample from Natural Bridges State Park also contained domoic acid at the federal alert level of 20 ppm.

By April the relative abundance of this diatom exceeded 95% at sampling sites in Santa Cruz and Monterey. Samples collected inside Santa Cruz Harbor by San Lorenzo Valley High School showed a pattern of peak abundance of *Pseudo-nitzschia* on April 1, decreasing slightly by April 9, then decreasing to very low levels by the end of the month. U.C. Santa Cruz reported continued high densities of *Pseudo-nitzschia australis* through early April, with densities decreasing by mid-month through the end of April. The highest relative abundance of this diatom in the Monterey area also occurred within the first week of April, decreasing significantly by the end of April. Elevated concentrations of domoic acid were detected in mussels from the Santa Cruz Pier during April and represented a further increase from the levels detected in March at this site. A mussel sample collected from Santa Cruz Pier on April 2 contained 80 ppm of domoic acid, decreasing to 22 ppm on April 9 and to 6 ppm on April 16. Mussels from Sunny Cove in Santa Cruz, collected on April 21, contained 2 ppm of domoic acid. Despite the low levels of domoic acid still present at the Santa Cruz sites by mid-month, mussels from Natural Bridges, located at the outer margin of Monterey Bay, did not contain a detectable level of this toxin. Anchovies collected by the Department's Food and Drug Branch contained high levels of domoic acid (35 - 59 ppm) that were slightly lower than the concentrations found in sardines fished from Monterey Bay in March.

As the Monterey Bay bloom declined in April there was a dramatic increase in the distribution and relative abundance of *Pseudo-nitzschia* along the southern California coast. The percent composition and relative abundance index for this diatom was greatest at sites from San Luis Obispo through Los Angeles counties (Figures 9-10, 12-13). There appeared to be a northward (up coast) progression over time, from Los Angeles to San Luis Obispo, in the detection of low concentrations of domoic acid in shellfish.

The relative abundance of *Pseudo-nitzschia* increased at sites in Santa Monica Bay (Los Angeles County) by April 10, with the greatest cell mass observed offshore in samples collected by the City of Los Angeles. A mussel sample collected on April 10 by the Los Angeles County Health Department from Portuguese Bend, just south of Santa Monica Bay, contained 3 ppm of domoic acid. *Pseudo-nitzschia* increased in abundance farther south at nearshore sites (Redondo and Cabrillo piers) by the end of the month. The highest relative abundance of this diatom along the Santa Barbara coast was observed at Gaviota Pier. *Pseudo-nitzschia* was also common farther down coast and inside Santa Barbara Harbor through the third week of the month. Oysters collected from a site approximately one-half mile offshore contained 3 ppm of domoic acid on April 21. Frequent sampling by volunteers revealed that *Pseudo-nitzschia* was a dominant component of the phytoplankton throughout most of April along the San Luis Obispo coast as well as inside Morro Bay. This diatom accounted for up to 97% of the species composition at a site offshore of Diablo Cove on April 11. A low concentration of domoic acid (2 ppm) was detected in a mussel sample collected from inside Morro Bay on April 27.

There was a continuing decline in the relative abundance of *Pseudo-nitzschia* throughout May along the Northern California coast. However, the distribution and relative abundance of this diatom continued to increase along the Southern California coast. The greatest densities were observed at sites along the Santa Barbara coast and offshore, although this diatom was dominant at most sites sampled in May. Thanks to the efforts of our field samplers and field observers in detecting the trend of increasing relative abundance of *Pseudo-nitzschia*, the program participants in our shellfish monitoring program increased their sampling effort for domoic acid analysis. This was especially true of the Los Angeles County Health Department public health investigators, who collected 16 samples from 14 different locations throughout the month. Following the pattern of increase observed for *Pseudo-nitzschia*, the concentration of domoic acid also increased through the first three weeks of May at sites along the Santa Barbara coast. Low levels of domoic acid were detected during the first week of May at two sites in Santa Barbara, increasing by the second week to concentrations well above the federal alert level of 20 ppm at Goleta Pier (76 ppm), at an offshore oil platform (92 ppm), and farther south at Long Beach (24 ppm) and Alamitos Bay (22 ppm) in Los Angeles County. As a result of the trend of increasing *Pseudo-nitzschia* densities and increasing domoic acid concentrations in Southern California, DHS issued a health advisory on May 16. The advisory warned consumers not to eat sport-harvested species of bivalve shellfish, sardines and anchovies, or the viscera of sport-harvested or commercially-sold lobster and crab (also known as lobster tomally and crab butter) harvested from the counties of Santa Barbara, Ventura, Los Angeles and Orange Counties. Elevated levels of domoic acid were detected in mussels, oysters, sardines and anchovies from this region.

During the third week of May the concentration of domoic acid increased at two offshore locations in Santa Barbara but decreased onshore at Goleta Pier. The highest concentration detected during this event was 140 ppm in mussels from an offshore oil platform in Santa Barbara Channel. By the end of May the concentrations of domoic acid had decreased significantly in Santa Barbara but persisted at low levels at several sites farther down coast along the Los Angeles and San Diego coastline. Domoic acid concentrations continued to decrease through June, with low levels detected in mussels from Morro Bay and from several sites in Santa Barbara.

Pseudo-nitzschia relative abundance increased at sites in Del Norte and Monterey counties in June and July. By August the distribution and relative abundance increased along much of the Northern California coast. Despite this increase the cell mass was relatively low in most areas. High relative abundances of this toxin producing diatom continued to be observed along the San Luis Obispo and Santa Barbara coast through August, but at fewer locations, and decreased significantly along the remainder of the southern California coast. The Catalina Tall Ships Expeditions educational program detected significant increases of *Pseudo-nitzschia* at several locations near the Channel Islands in July, covering a wide area from Santa Rosa Island to Catalina Island. Numbers of this diatom decreased by August in this offshore region.

Pseudo-nitzschia remained abundant at the Monterey commercial pier inside Monterey Bay during September and was common at sites along the Santa Cruz shoreline inside the bay. Low levels of domoic acid were detected in mussels from the Santa Cruz Pier (2.8 ppm) and Natural Bridges State Park (1.4 ppm) in Santa Cruz County on September 10 (Figure 4). The Department's Food and Drug Branch obtained samples of sardines fished from Monterey Bay, which were found to contain domoic acid at concentrations above the federal alert level of 20 ppm. As a result the Department issued a Health Advisory on September 22. The distribution and relative abundance of *Pseudo-nitzschia* decreased in Santa Barbara but remained high along the San Luis Obispo coast, with cell mass increasing significantly offshore of Diablo Cove.

Pseudo-nitzschia relative abundance and distribution increased at most Northern California locations throughout October. Low levels of domoic acid were detected in mussels from the Mile Buoy in Monterey Bay (3 ppm) on October 2 and in rock crab viscera from Bodega Harbor (7 ppm) on October 29. A high concentration of domoic acid was detected in rock crab viscera from Drakes Bay (41 ug) on October 29. Mussel samples from other Northern California sites did not contain detectable levels of this toxin. *Pseudo-nitzschia* continued to be abundant inside Humboldt Bay through November, however the overall cell density was low. The elevated numbers in the San Luis Obispo region persisted through November and declined somewhat through December. Domoic acid was not detected in shellfish samples from Southern California locations after June 8.

Marine Mammal Impacts

The high levels of domoic acid along the California coast resulted in health impacts to numerous marine mammal species, with sea lions and common dolphins suffering the greatest losses. The elevated levels of *Pseudo-nitzschia* and domoic acid detected along the Southern California coast resulted in strandings in early May. On May 10 the Los Angeles Times reported that more than 30 sea lions had washed up on beaches in Los Angeles, Ventura and Orange County beaches during the first week of May. The National Marine Fisheries Service's California Marine Mammal Stranding Network[1] documented total suspected domoic acid-related strandings of 506 California seal lions and 50 common dolphins during May 2003. The majority of sea lion strandings

[1] *Thanks to Joe Cordero for data from the U.S. Department of Commerce, NOAA/National Marine Fisheries Service, Southwest Region, California Marine Mammal Stranding Network Database.*

occurred between Santa Barbara and Ventura counties, with a range from Santa Cruz to San Diego counties. Common dolphin strandings were most numerous in Ventura County in May. Between January 1 and December 31, the California Marine Mammal Stranding Network recorded 1174 California sea lion and 125 common dolphin strandings suspected of being related to domoic acid poisoning. The greatest numbers occurred between Santa Barbara and Orange counties.

2003 PSP QUARANTINES AND RELATED HEALTH ADVISORIES

The annual quarantine on sport-harvested mussels was implemented as usual on May 1. This annual quarantine applies only to sport-harvested mussels along the entire California coastline, including all bays and estuaries. This annual quarantine normally begins on May 1 of each year and is rescinded at midnight on October 31.

On May 16 the state health director issued a health advisory warning consumers not to eat sport-harvested species of bivalve shellfish, sardines and anchovies, or the viscera of sport-harvested or commercially-sold lobster and crab (also known as lobster tomally and crab butter) harvested from the Southern California coast. This action was a result of the observation by the Marine Biotoxin Monitoring Program of increasing *Pseudo-nitzschia* densities and increasing domoic acid concentrations in this region. Elevated levels of domoic acid were detected in mussels, oysters, sardines and anchovies from Santa Barbara, Ventura, Los Angeles and Orange Counties.

A health advisory was issued for Monterey Bay on September 22 as a result of the observation of increasing *Pseudo-nitzschia* densities in this region and the subsequent detection of elevated levels of domoic acid in sardines and lower levels in shellfish. The public was advised to avoid eating sport-harvested species of sardines, anchovies, shellfish, or crab viscera from the portions of Santa Cruz and Monterey counties that border Monterey Bay.

The annual mussel quarantine, which normally terminates on October 31 at midnight, was extended on October 30 as a result of elevated levels of marine biotoxins along the coast. On November 21 the extended annual quarantine was rescinded.

There were no reported human illnesses or deaths due to PSP or domoic acid poisoning in 2003.

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TABLES 1 – 8

Table 1. Total number of shellfish samples collected per coastal county in 2003 for PSP assay.

COUNTY	# SAMPLES
Del Norte	15
Humboldt	111
Mendocino	9
Sonoma	16
Marin	388
San Francisco	15
San Mateo	21
Santa Cruz	68
Monterey	3
San Luis Obispo	112
Santa Barbara	100
Ventura	12
Los Angeles	73
Orange	57
San Diego	86
TOTAL	**1086**

Table 2. Number of shellfish samples collected by program participants, per coastal county, in 2003 for PSP assay.

COUNTY (North to South)	COMMERCIAL GROWERS	COUNTY AGENCIES	STATE AGENCIES	FEDERAL AGENCIES	OTHER PARTICIPANTS	TOTAL
Del Norte	--	15	--	--	--	15
Humboldt	105	6	--	--	--	111
Mendocino	--	8	--	--	1	9
Sonoma	--	6	9	--	1	16
Marin	372	--	16	--	--	388
San Francisco	--	15	--	--	--	15
San Mateo	--	21	--	--	--	21
Santa Cruz	--	18	50	--	--	68
Monterey	--	--	3	--	--	3
San Luis Obispo	102	--	10	--	--	112
Santa Barbara	38	--	61	1	--	100
Ventura	--	7	--	--	5	12
Los Angeles	--	44	3	--	26	73
Orange	46	11	--	--	--	57
San Diego	51	--	--	7	28	86
TOTAL =	**714**	**151**	**152**	**8**	**61**	**1086**

Table 3. Program participants by county that submitted shellfish samples in 2003 for PSP assay.

COUNTY	AGENCY
Del Norte	Del Norte County Health Department
Humboldt	Humboldt County Environmental Health Department
	Coast Seafoods Company
Mendocino	Mendocino County Environmental Health Department
	DHS Volunteer
Sonoma	Sonoma County Public Health Department
	California Department of Fish and Game
	DHS Marine Biotoxin Monitoring Program
	DHS Volunteer
Marin	DHS Marine Biotoxin Monitoring Program
	Cove Mussel Company
	Hog Island Oyster Company
	Johnson Oyster Company
San Francisco	San Francisco County Health Department
San Mateo	San Mateo County Environmental Health Department
Santa Cruz	Santa Cruz County Environmental Health Department
	University of California Santa Cruz
Monterey	University of California Santa Cruz
San Luis Obispo	Williams Shellfish Company
	University of California Santa Barbara Marine Science Institute
Santa Barbara	University of California Santa Barbara Marine Science Institute
	California Department of Parks and Recreation
	Vandenberg Air Force Base, Environmental Health Services
	Santa Barbara Mariculture Company
Ventura	Ventura County Environmental Health Department
	DHS Volunteer
Los Angeles	Los Angeles County Health Department
	Aquarium of the Pacific Long Beach
	Los Angeles Regional Water Quality Control Board
	DHS Volunteer
Orange	Orange County Health Care Agency
	Ecomar, Inc.

San Diego	Carlsbad Aquafarm, Inc.
	DHS Volunteer
	Scripps Institute of Oceanography
	U.S. Navy

Table 4. Number and species of samples collected in 2003 for PSP assay.

SAMPLE TYPE	# SAMPLES
Bay Mussels[2]:	
Sentinel	138
Wild	62
Cultured	130
Total Bay Mussels	***330***
Sea Mussels[3]:	
Sentinel	120
Wild	316
Total Sea Mussels	***436***
Mixed Bay and Sea Mussels	3
Total Mussels	**769**
Pacific Oysters[4]	
Cultured	**301**
Rock Scallops	**7**
Other[5]	**9**
TOTAL	**1086**

[2] *Mytilus edulis or M. galloprovincialis*
[3] *Mytilus californianus*
[4] *Crassostrea gigas*
[5] *Washington clams (3 samples), Basket Cockles (1), Gaper Clams (1), Spiny Lobster (1), and Brown Rock Crab (1)*

Table 5. Total number of shellfish samples analyzed for domoic acid, per coastal county, in 2003.

COUNTY	# SAMPLES
Del Norte	3
Humboldt	8
Mendocino	0
Sonoma	8
Marin	10
San Francisco	0
San Mateo	3
Santa Cruz	34
Monterey	1
San Luis Obispo	34
Santa Barbara	35
Ventura	8
Los Angeles	30
Orange	15
San Diego	19
TOTAL	**208**

Table 6. Total number of phytoplankton samples collected per coastal county in 2003.

COUNTY	# SAMPLES
Del Norte	30
Humboldt	51
Mendocino	15
Sonoma	19
Marin	248
Contra Costa	1
Alameda	1
San Francisco	33
San Mateo	29
Santa Cruz	42
Monterey	32
San Luis Obispo	142
Santa Barbara	122
Ventura	11
Los Angeles	164
Orange	60
San Diego	97
TOTAL	**1097**

Table 7. Date and location of shellfish samples containing detectable levels of PSP toxins during 2003.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	PSP TOXINS (ug/100 g)
FEBRUARY				
02/11/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
02/13/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	38
02/14/03	Sonoma	Washington Clam, viscera	Bodega Harbor, outer	43
02/18/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
02/18/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
02/20/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
02/25/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
02/26/03	Los Angeles	Sea Mussel, wild	Portuguese Bend	38
02/28/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	39
MARCH				
03/04/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	42
03/04/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
03/11/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	48
03/11/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	47
03/18/03	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	67
03/18/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	55
03/18/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	45
03/19/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	39
03/19/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	47
03/19/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	40
03/19/03	Santa Barbara	Sea Mussel, wild	Goleta Pier	39
03/25/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	43
03/25/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	38
APRIL				
04/01/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	39
04/02/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	46
04/08/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	40
04/09/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	46
04/10/03	San Mateo	Sea Mussel, wild	Pescadero State Beach	40

04/15/03	Marin	Sea Mussel, wild	Drakes Bay, Chimney Rock LBS	42
04/15/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	40
04/15/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	39
04/18/03	San Francisco	Sea Mussel, Sentinel	China Beach	38
04/21/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	48
04/21/03	Santa Cruz	Sea Mussel, wild	Santa Cruz, Sunny Cove	39
04/22/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	43
04/22/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	39
04/23/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	47
04/27/03	San Luis Obispo	Bay Mussel, cultured	Morro Bay	39
04/29/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	43
04/29/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
MAY				
05/01/03	San Francisco	Bay Mussel, wild	China Beach	41
05/06/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	50
05/06/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	72
05/07/03	Monterey	Sea Mussel, wild	Monterey Bay, M1	49
05/08/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	47
05/08/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	58
05/12/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	39
05/12/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	40
JULY				
07/15/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	43
07/22/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	40
07/22/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	45
07/29/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	44
07/29/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
AUGUST				
08/04/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	40
08/05/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	46
08/05/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	47
08/07/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	39
08/07/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	48
08/11/03	Humboldt	Sea Mussel, wild	Trinidad Head	42

08/12/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	43
08/12/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	47
08/12/03	Mendocino	Sea Mussel, wild	Fort Bragg	42
08/18/03	Marin	Sea Mussel, wild	Drakes Bay, Chimney Rock LBS	42
08/18/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
08/18/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	39
08/19/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	40
08/19/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	48
08/20/03	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	41
08/20/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	40
08/25/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
08/26/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	52
08/26/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	48
08/27/03	Humboldt	Sea Mussel, wild	Humboldt, Moonstone Beach	81
08/27/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	43
08/28/03	Mendocino	Sea Mussel, wild	Fort Bragg	120
SEPTEMBER				
09/02/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	45
09/02/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	47
09/02/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	42
09/02/03	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	40
09/09/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	44
09/09/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	53
09/10/03	Del Norte	Sea Mussel, wild	Point St. George	50
09/10/03	Humboldt	Sea Mussel, wild	Little River State Park	56
09/11/03	Marin	Bay Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	47
09/15/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	43
09/15/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	65
09/16/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	47
09/16/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	51
09/16/03	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-11	39
09/17/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	54
09/17/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	57
09/17/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	55

09/22/03	Sonoma	Sea Mussel, wild	Salt Point State Park	46
09/22/03	Marin	Bay Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	47
09/22/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	45
09/22/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	50
09/22/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	44
09/23/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	50
09/25/03	San Mateo	Sea Mussel, wild	Pescadero State Beach	40
09/29/03	Mendocino	Sea Mussel, wild	Fort Bragg	1601
09/29/03	Sonoma	Sea Mussel, wild	Salt Point State Park	108
09/29/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	44
09/29/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	45
09/29/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	49
09/30/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	43
09/30/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	67
OCTOBER				
10/05/03	San Luis Obispo	Bay Mussel, cultured	Morro Bay	41
10/06/03	Sonoma	Sea Mussel, wild	Salt Point State Park	45
10/07/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	45
10/07/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	43
10/07/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	48
10/07/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	49
10/07/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	45
10/07/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	48
10/13/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	44
10/13/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	46
10/13/03	San Luis Obispo	Bay Mussel, cultured	Morro Bay	47
10/14/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	42
10/14/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	47
10/15/03	San Luis Obispo	Sea Mussel, wild	San Luis Obispo, Avila Pier	42
10/19/03	San Luis Obispo	Bay Mussel, cultured	Morro Bay	45
10/20/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
10/20/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	44
10/21/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	43
10/21/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	47

10/22/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	67
10/25/03	Mendocino	Sea Mussel, wild	Mackerricher State Park	63
10/26/03	Del Norte	Sea Mussel, wild	Point St. George	56
10/27/03	Mendocino	Sea Mussel, wild	Fort Bragg	147
10/27/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	80
10/27/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	185
10/27/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	74
10/27/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	56
10/27/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	65
10/27/03	San Luis Obispo	Bay Mussel, cultured	Morro Bay	44
10/28/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	44
10/28/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	44
10/28/03	Marin	Sea Mussel, wild	Drakes Bay, Chimney Rock LBS	79
10/28/03	San Mateo	Sea Mussel, wild	Pescadero State Beach	43
10/28/03	Santa Cruz	Sea Mussel, wild	Natural Bridges	44
10/28/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	38
10/29/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	185
10/29/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	334
10/29/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	132
10/29/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	108
10/30/03	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	48
10/30/03	Marin	Sea Mussel, wild	Drakes Bay, Chimney Rock LBS	153
10/30/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	81
10/30/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	109
10/30/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	66
10/30/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	209
NOVEMBER				
11/03/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	61
11/03/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	67
11/03/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	59
11/03/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	111
11/04/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	42
11/04/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	48

11/04/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	78
11/04/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	52
11/04/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	106
11/04/03	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	58
11/05/03	San Mateo	Sea Mussel, wild	Pescadero State Beach	43
11/05/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	75
11/06/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	59
11/06/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	69
11/06/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	54
11/06/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	107
11/10/03	Mendocino	Sea Mussel, wild	Fort Bragg	59
11/10/03	Sonoma	Sea Mussel, wild	Bodega Harbor, USCG Dock	80
11/11/03	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	39
11/11/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	49
11/11/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	49
11/11/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	40
11/11/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	56
11/12/03	Marin	Sea Mussel, wild	Drakes Bay, Chimney Rock LBS	47
11/12/03	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	45
11/12/03	San Mateo	Sea Mussel, wild	Pescadero State Beach	43
11/12/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	65
11/13/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	51
11/13/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	48
11/13/03	Santa Cruz	Sea Mussel, wild	Natural Bridges	53
11/13/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	48
11/17/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	42
11/17/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	51
11/17/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	52
11/18/03	Sonoma	Sea Mussel, wild	Bodega Harbor, USCG Dock	49
11/18/03	Marin	Sea Mussel, wild	Drakes Bay, Chimney Rock LBS	41
11/18/03	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-11	40
11/23/03	Del Norte	Sea Mussel, wild	Point St. George	43
11/24/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	41

11/24/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	46
11/24/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	46
11/25/03	San Mateo	Sea Mussel, wild	Pescadero State Beach	45
11/26/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	50
DECEMBER				
12/01/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
12/01/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	38
12/09/03	San Mateo	Sea Mussel, wild	Pescadero State Beach	40
12/15/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	40
12/15/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
12/22/03	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	38
12/22/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	45
12/22/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
12/22/03	Santa Cruz	Sea Mussel, wild	Natural Bridges	43
12/23/03	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	43
12/26/03	San Mateo	Sea Mussel, wild	Pescadero State Beach	39
12/29/03	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	43
12/30/03	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	46

Table 8. Date and location of shellfish samples containing detectable levels of domoic acid toxins during 2003.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	DA (ppm)
JANUARY				
01/03/03	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	110
MARCH				
03/12/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	32
03/14/03	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	52
03/19/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	3
03/26/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	68
03/27/03	Santa Cruz	Sea Mussel, wild	Natural Bridges	20
APRIL				
04/02/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	80
04/09/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	22
04/10/03	Los Angeles	Sea Mussel, wild	Portuguese Bend	2.6
04/16/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	6
04/21/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	2.1
04/21/03	Santa Cruz	Sea Mussel, wild	Santa Cruz, Sunny Cove	2.2
04/21/03	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	2.7
04/27/03	San Luis Obispo	Bay Mussel, cultured	Morro Bay	2.1
MAY				
05/06/03	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	7
05/07/03	Santa Barbara	Sea Mussel, wild	Goleta Pier	3
05/10/03	Los Angeles	Sea Mussel, wild	Cabrillo Beach	9.5
05/11/03	Santa Barbara	Sea Mussel, wild	Santa Barbara Ch., Plt. Gina	92
05/12/03	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	13
05/12/03	Orange	Sea Mussel, wild	Newport Beach Pier	2.2
05/13/03	Los Angeles	Bay Mussel, wild	Long Beach	24
05/13/03	Los Angeles	Sea Mussel, wild	Los Angeles, Alamitos Bay	22
05/14/03	Santa Barbara	Sea Mussel, wild	Goleta Pier	76
05/14/03	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	26
05/16/03	Santa Barbara	Sea Mussel, wild	Santa Barbara Ch., Plt Houchin	140
05/19/03	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	61

05/20/03	Los Angeles	Sea Mussel, wild	Portuguese Bend	16
05/21/03	Santa Barbara	Sea Mussel, wild	Goleta Pier	10
05/21/03	Los Angeles	Sea Mussel, wild	Leo Carillo State Beach	20
05/22/03	Los Angeles	Sea Mussel, wild	Portuguese Bend	3
05/22/03	Los Angeles	Sea Mussel, wild	Whites Landing	5
05/23/03	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon	1
05/25/03	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	3
JUNE				
06/03/03	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	10
06/07/03	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	3.1
06/08/03	Santa Barbara	Sea Mussel, wild	Gaviota State Beach	5.1
06/16/03	San Luis Obispo	Bay Mussel, cultured	Morro Bay	3
AUGUST				
08/11/03	Humboldt	Sea Mussel, wild	Trinidad Head	1.5
SEPTEMBER				
09/10/03	Santa Cruz	Sea Mussel, wild	Natural Bridges	1.4
09/10/03	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	2.8
OCTOBER				
10/02/03	Santa Cruz	Sea Mussel, wild	Santa Cruz, Mile Buoy	3
10/29/03	Sonoma	Crab, Red Rock, viscera	Bodega Harbor, USCG Dock	7.3
10/29/03	Marin	Crab, Red Rock, viscera	Drakes Bay, Chimney Rock LBS	6.8
10/29/03	Marin	Crab, Red Rock, viscera	Drakes Bay, Chimney Rock LBS	17
10/29/03	Marin	Crab, Red Rock, viscera	Drakes Bay, Chimney Rock LBS	41
NOVEMBER				
11/02/03	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	48.1

FIGURES 1 – 13.

Figure 1a. Locations of shellfish sampling stations during 2003 (Del Norte to Monterey counties).

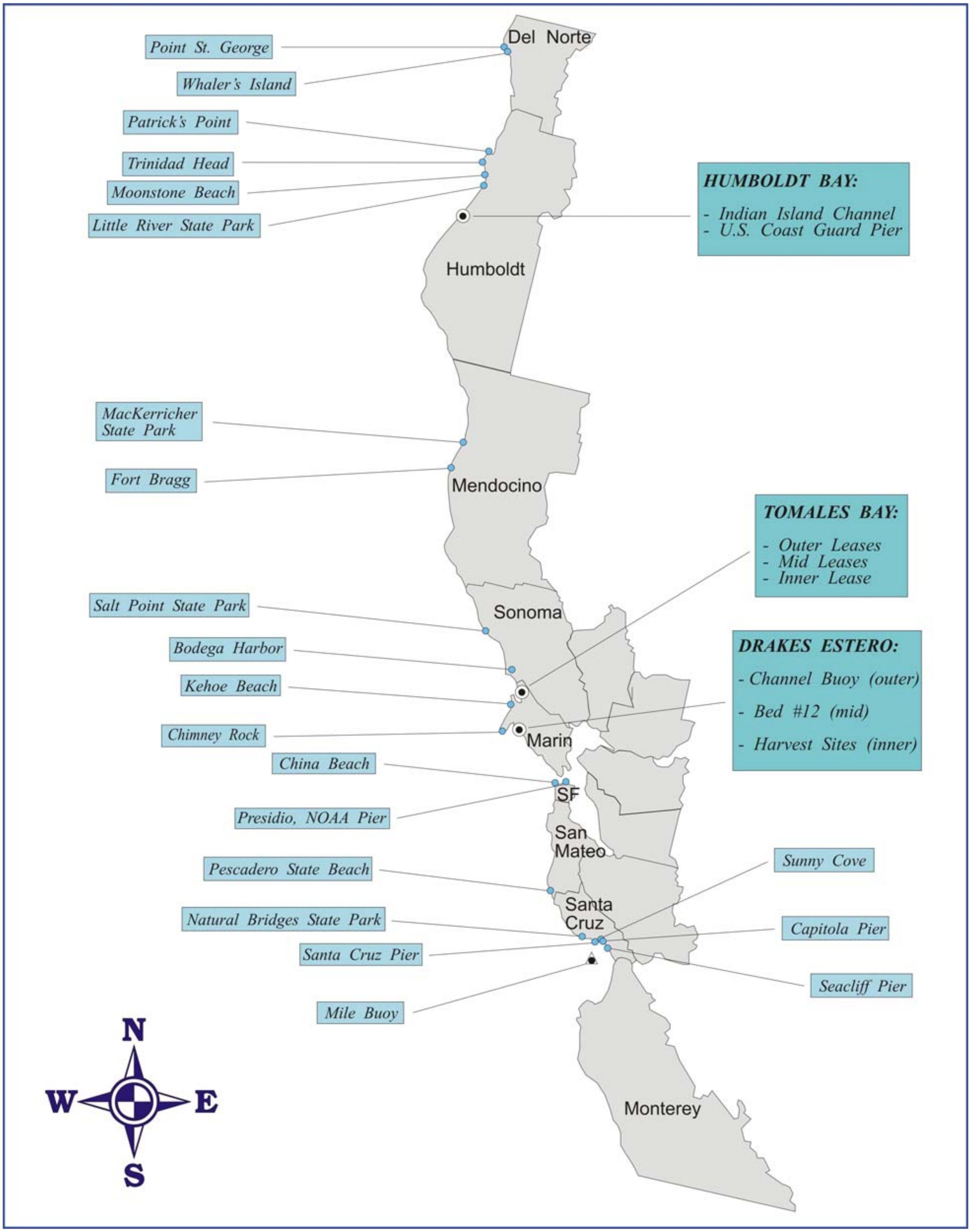

Figure 1b. Locations of shellfish sampling stations during 2003 (San Luis Obispo to San Diego counties).

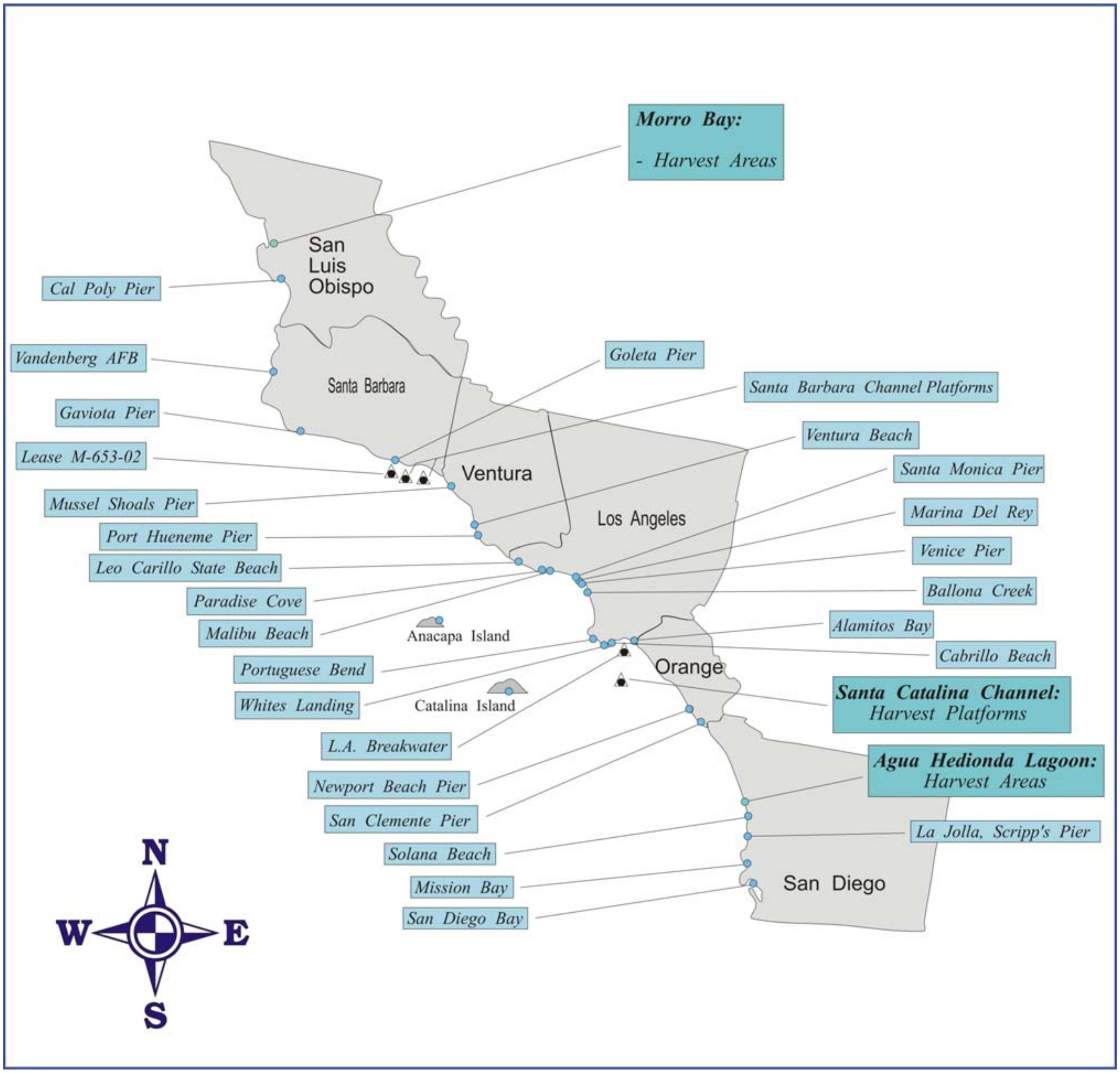

Figure 1c. Locations of phytoplankton sampling stations during 2003 (Del Norte to Monterey counties).

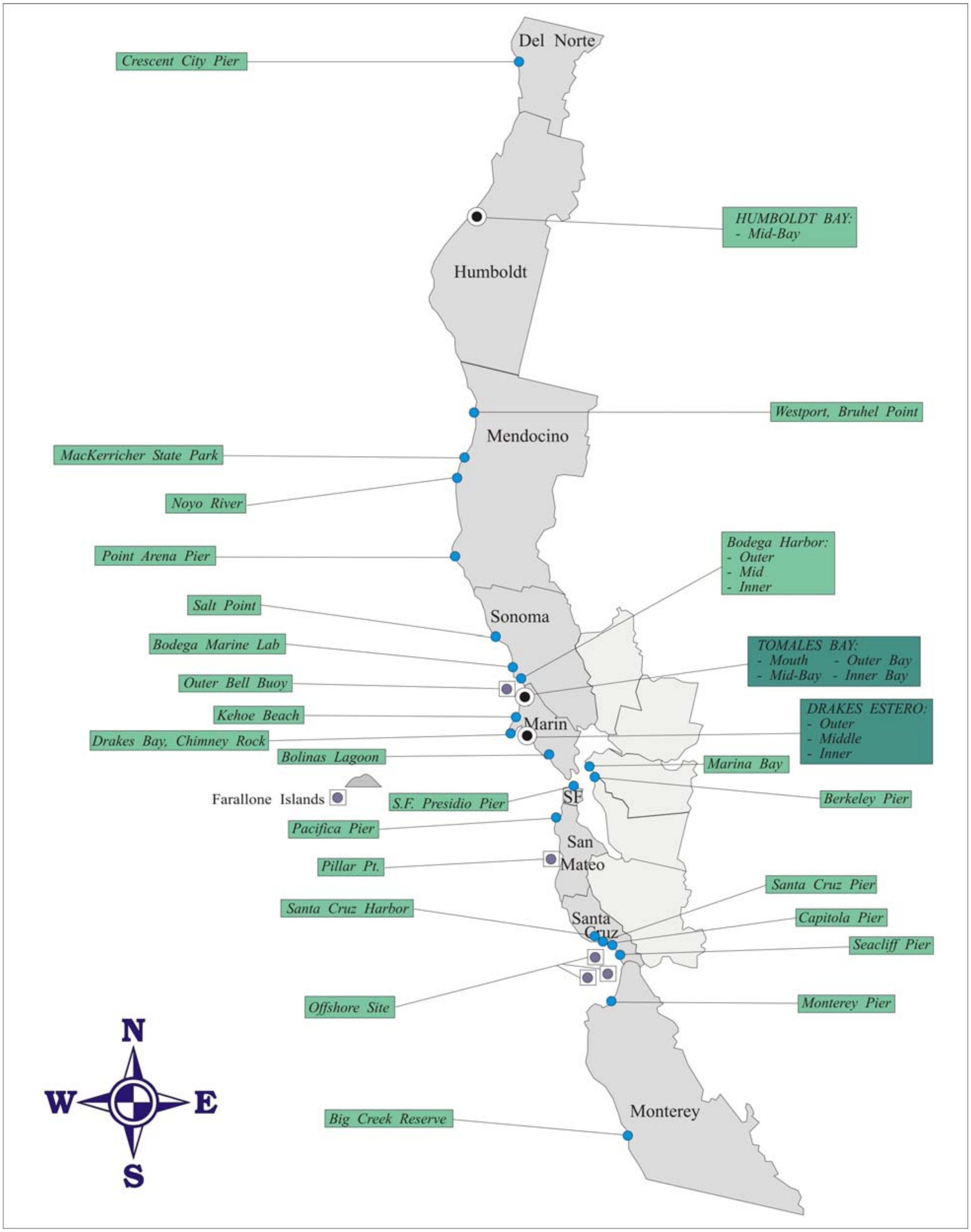

Figure 1d. Locations of phytoplankton sampling stations during 2003 (San Luis Obispo to San Diego counties).

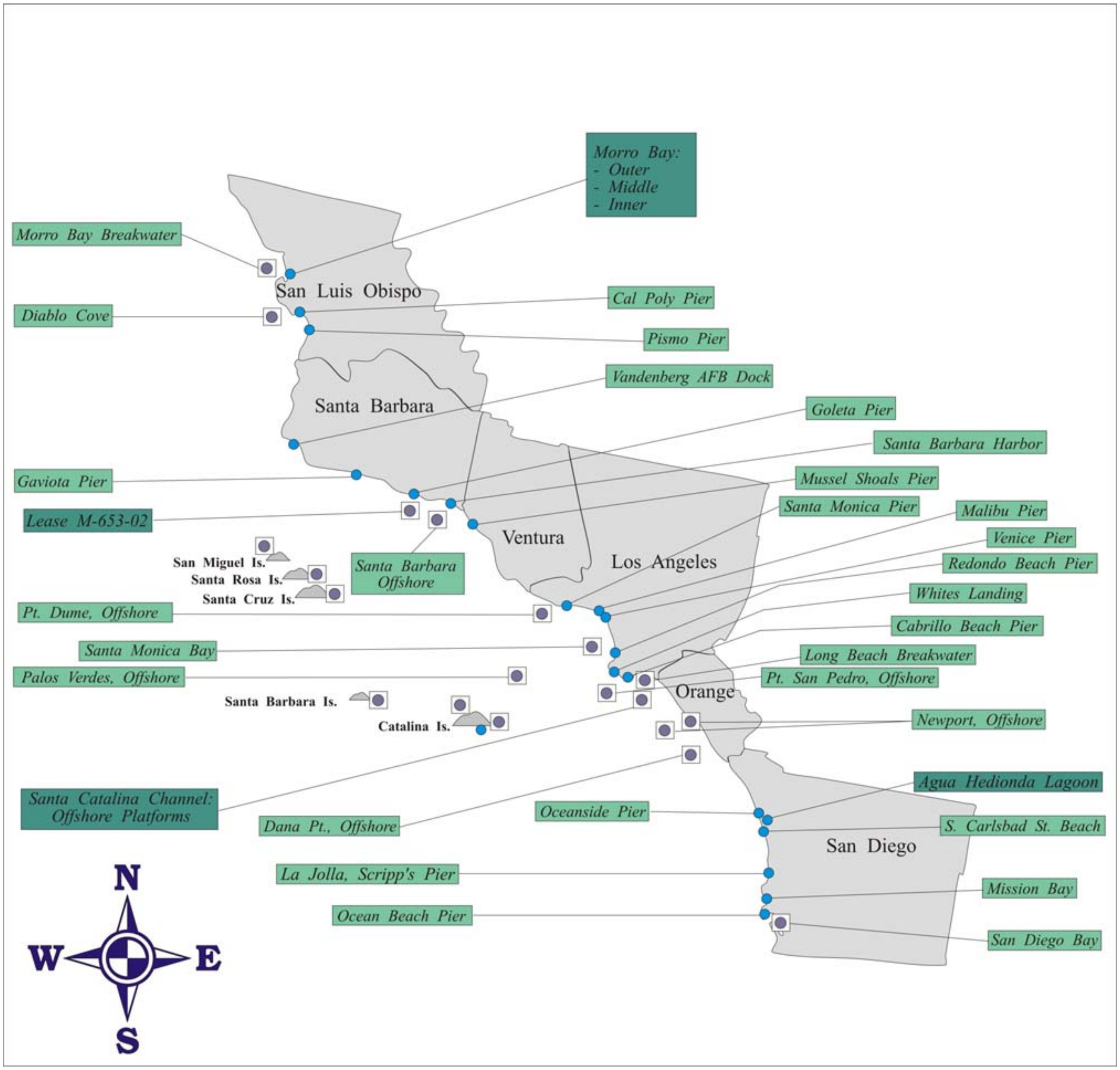

Figure 2. Annual PSP toxin levels in California shellfish from 1991 through 2003.

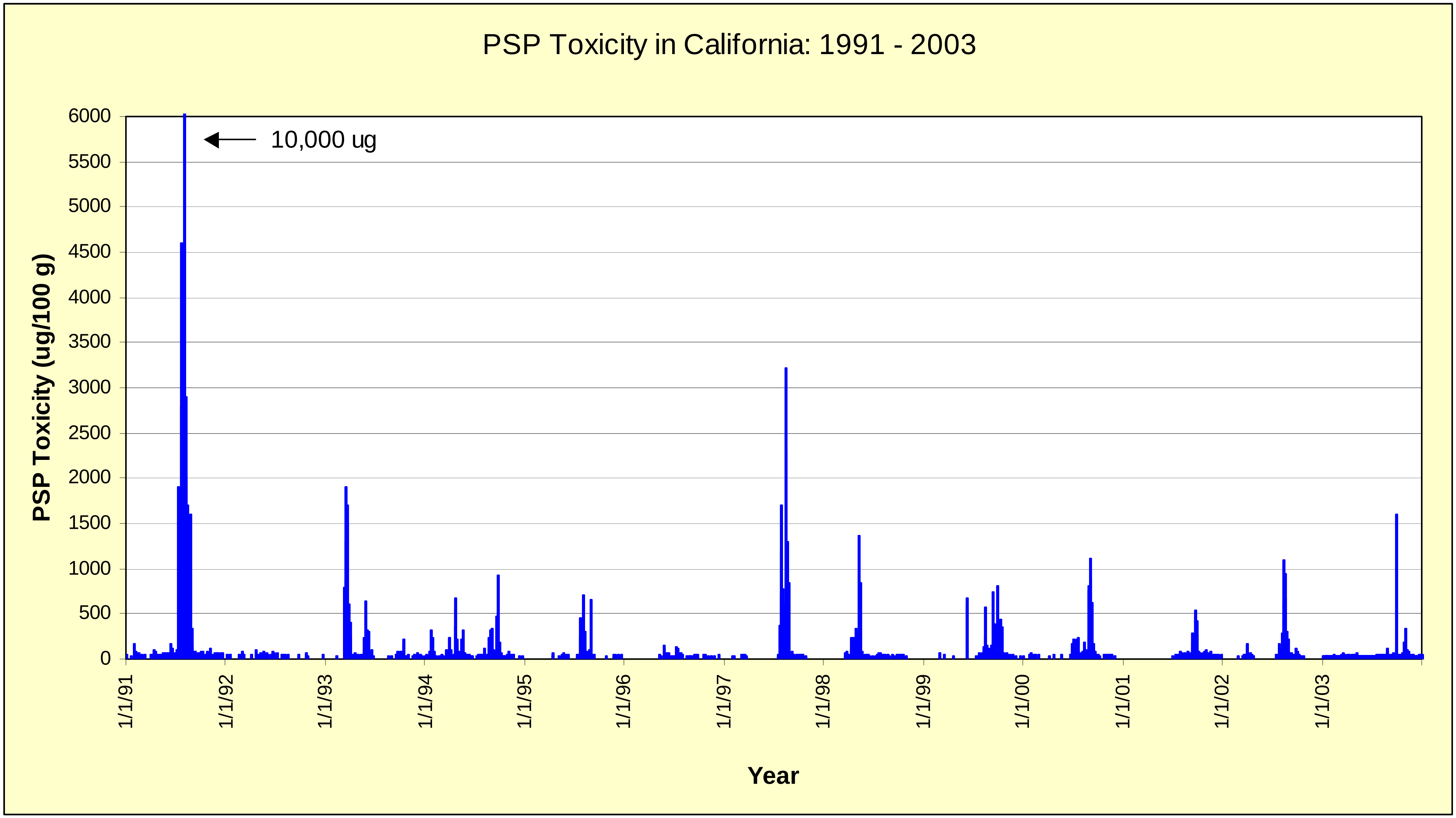

Figure 3. PSP toxin concentration and temporal distribution in California shellfish during 2003.

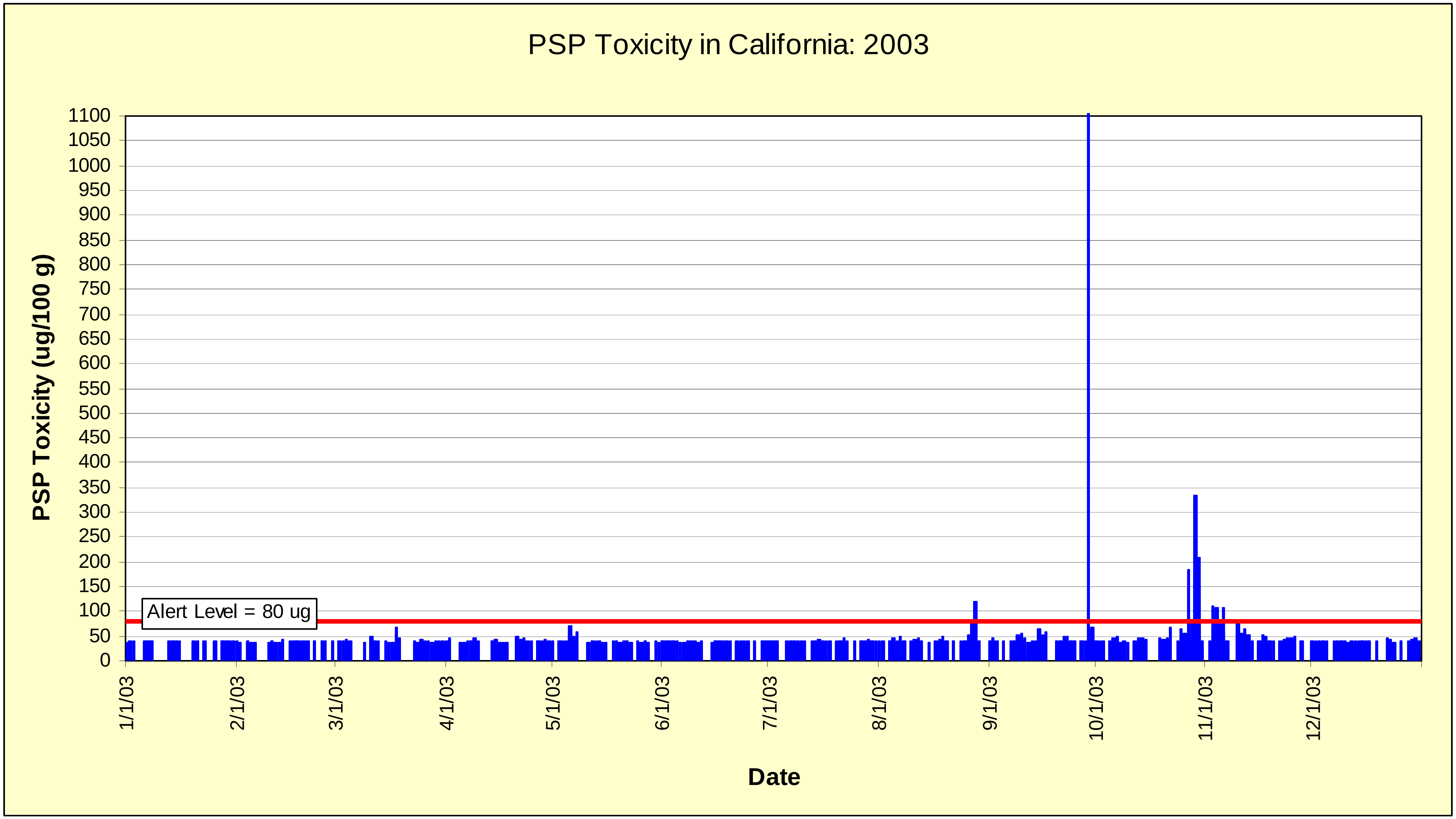

Figure 4. Temporal distribution and percent composition of *Alexandrium spp.* (northern counties).

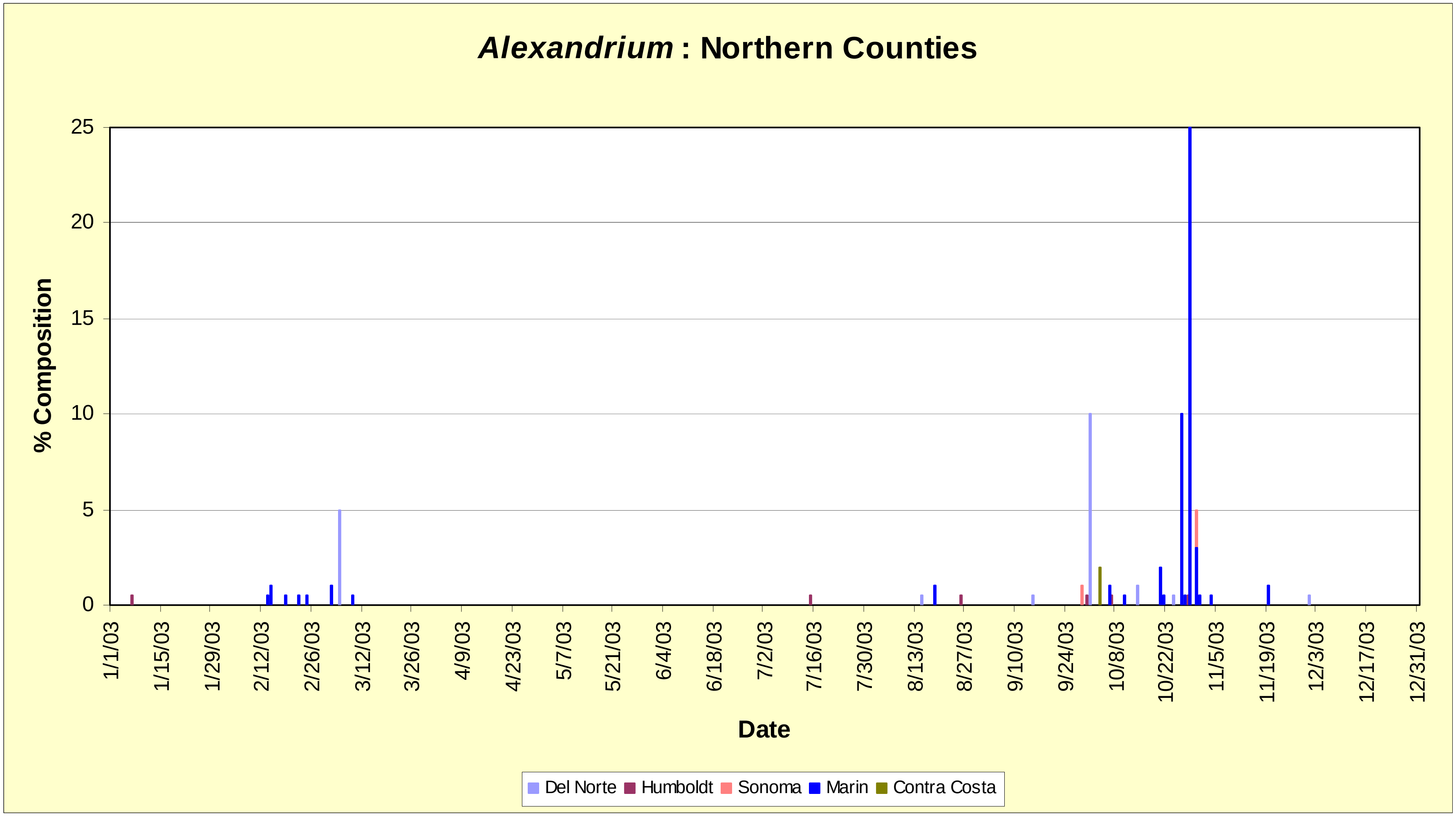

Figure 5. Temporal distribution and percent composition of *Alexandrium spp.* (central counties).

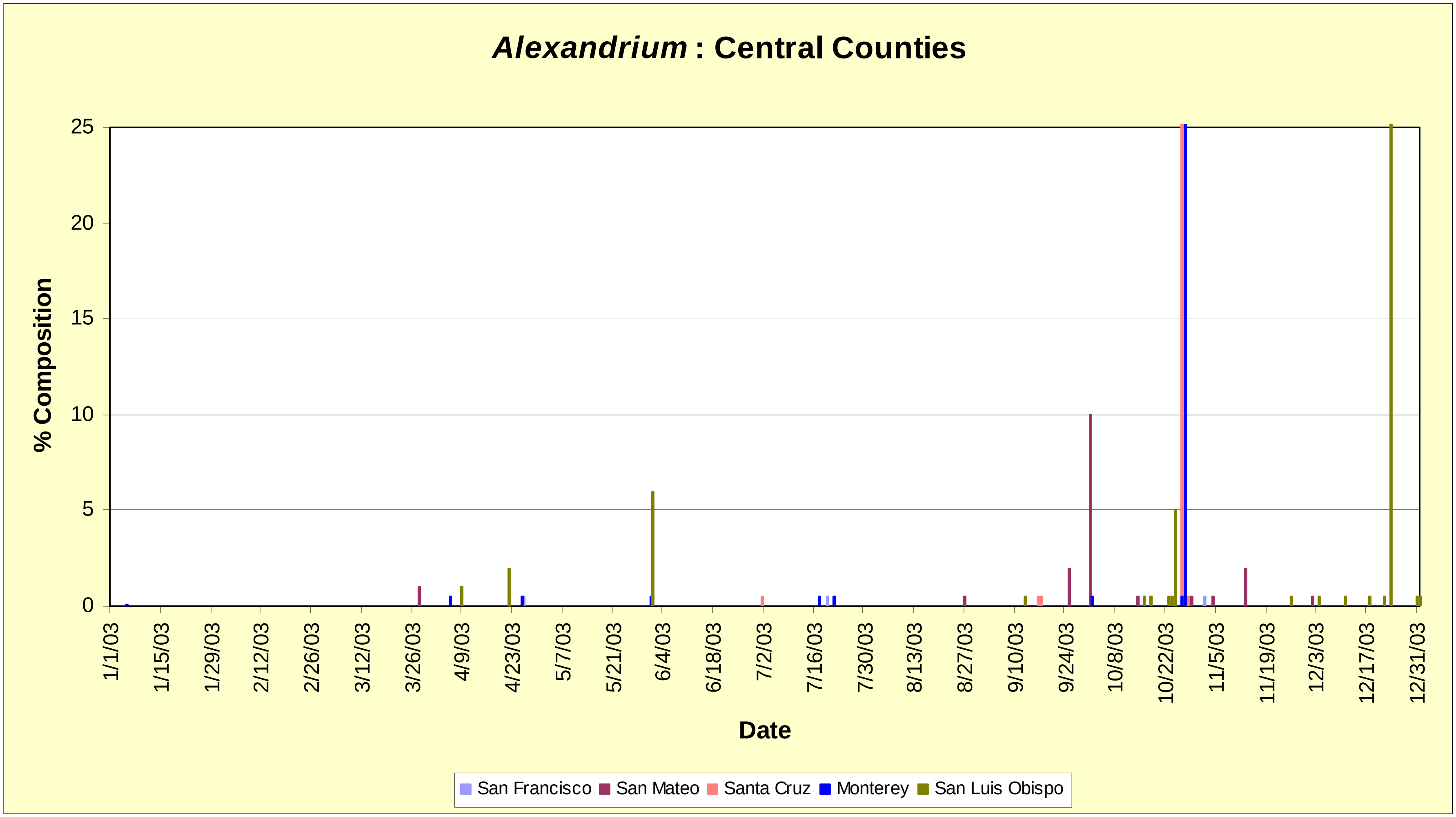

Figure 6. Temporal distribution and percent composition of *Alexandrium spp.* (southern counties).

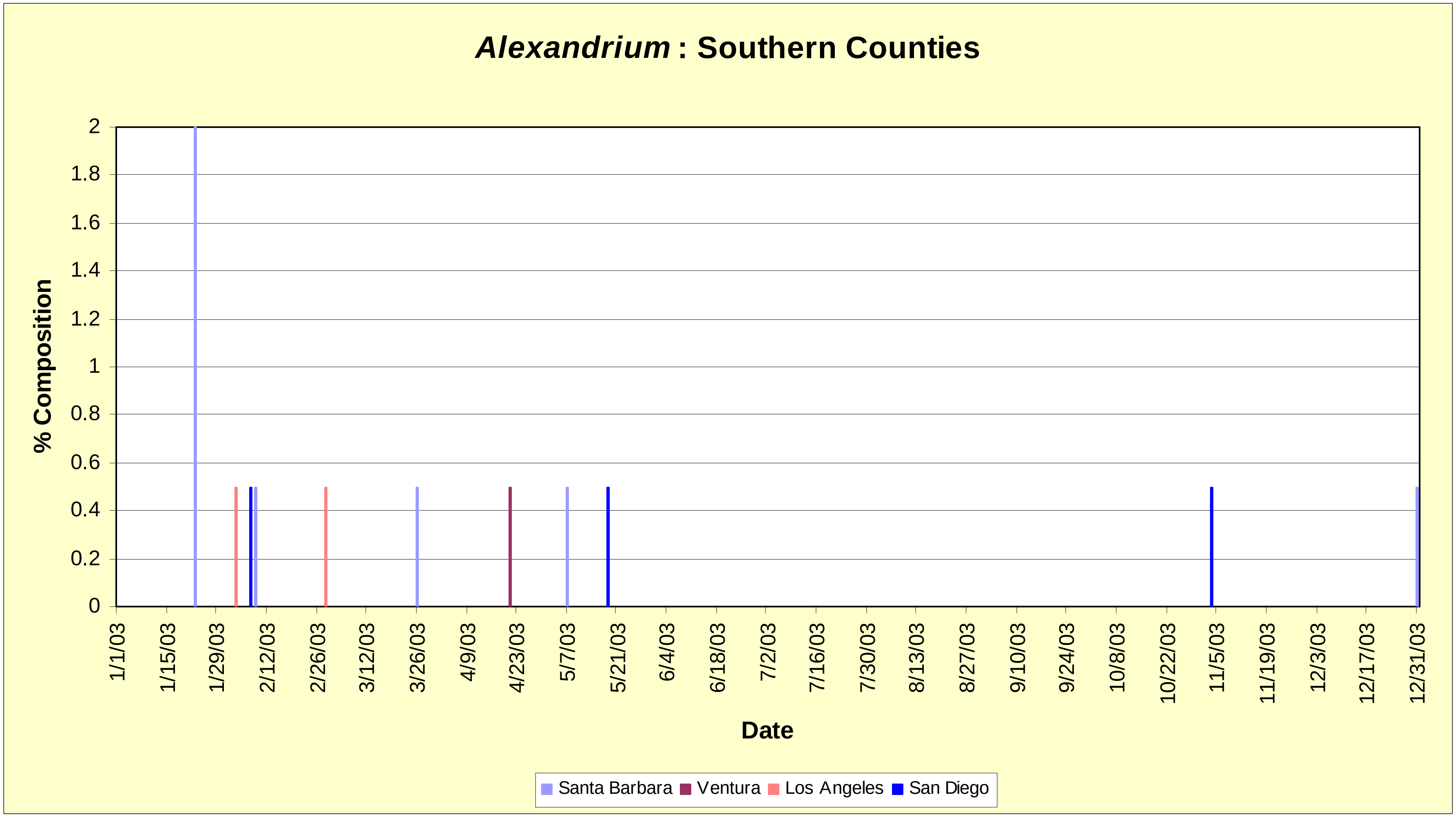

Figure 7. Domoic acid concentration and temporal distribution in California shellfish during 2003.

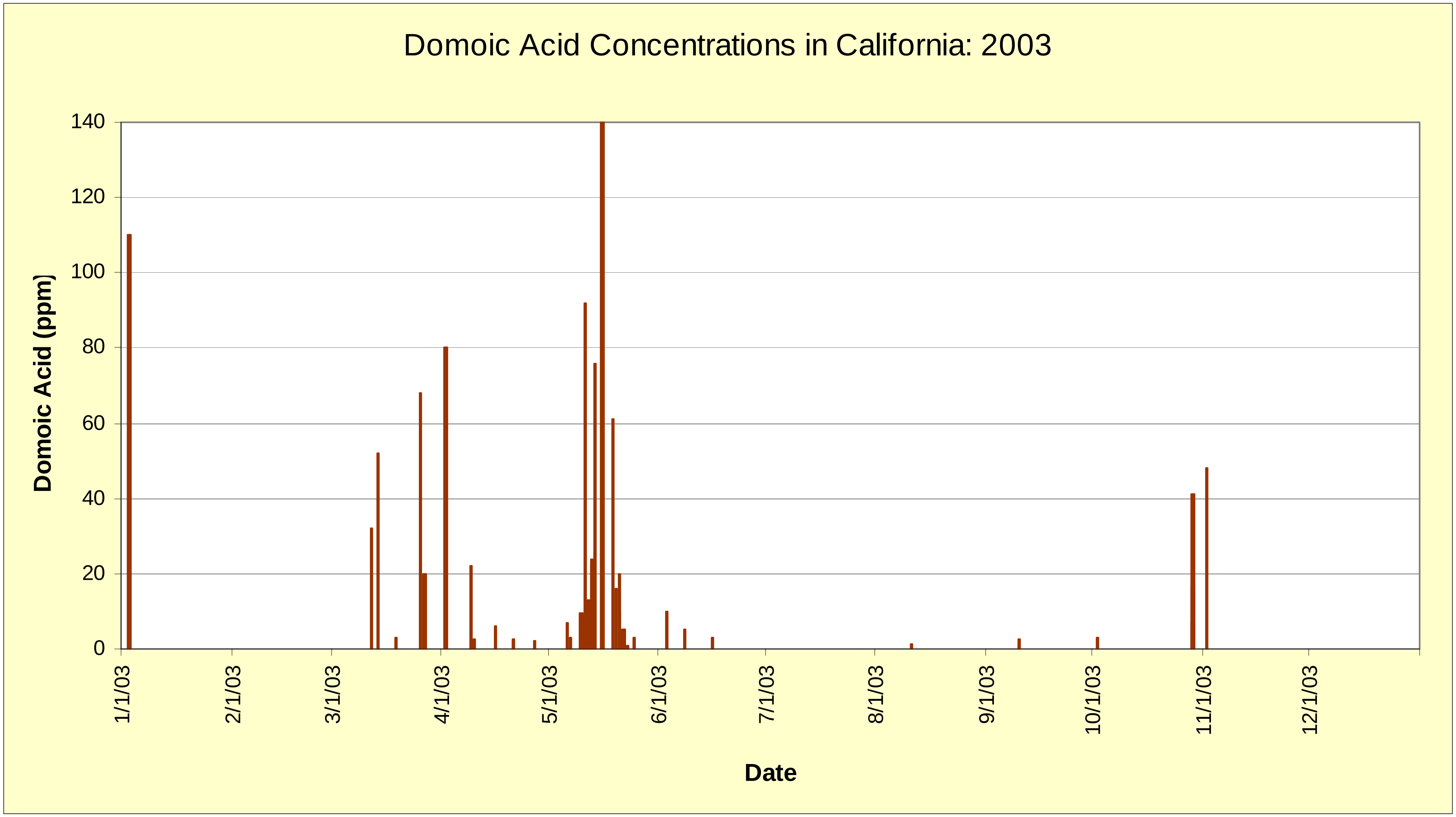

Figure 8. Temporal distribution and percent composition of *Pseudo-nitzschia spp.* (northern counties).

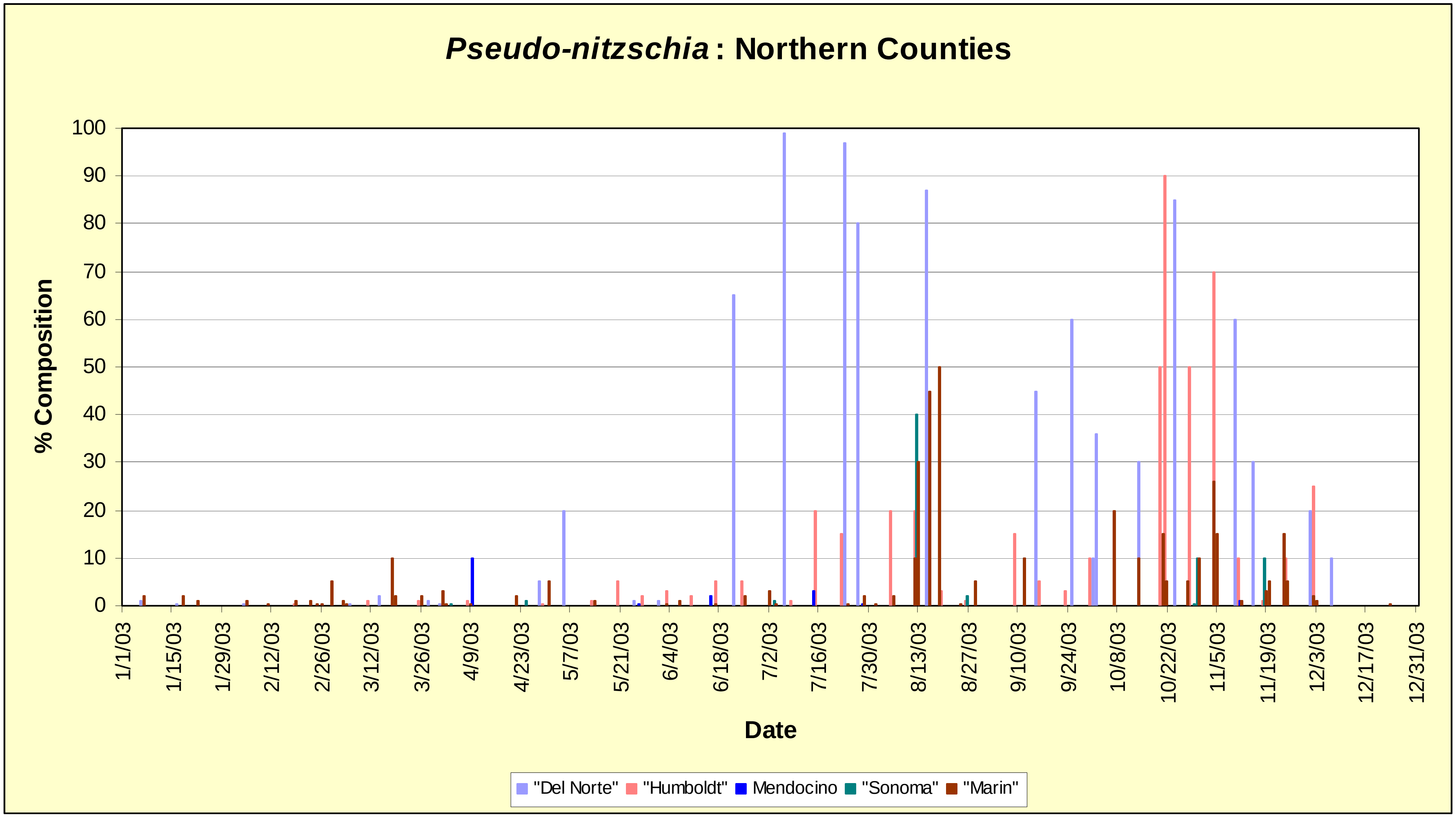

Figure 9. Temporal distribution and percent composition of *Pseudo-nitzschia spp.* (central counties).

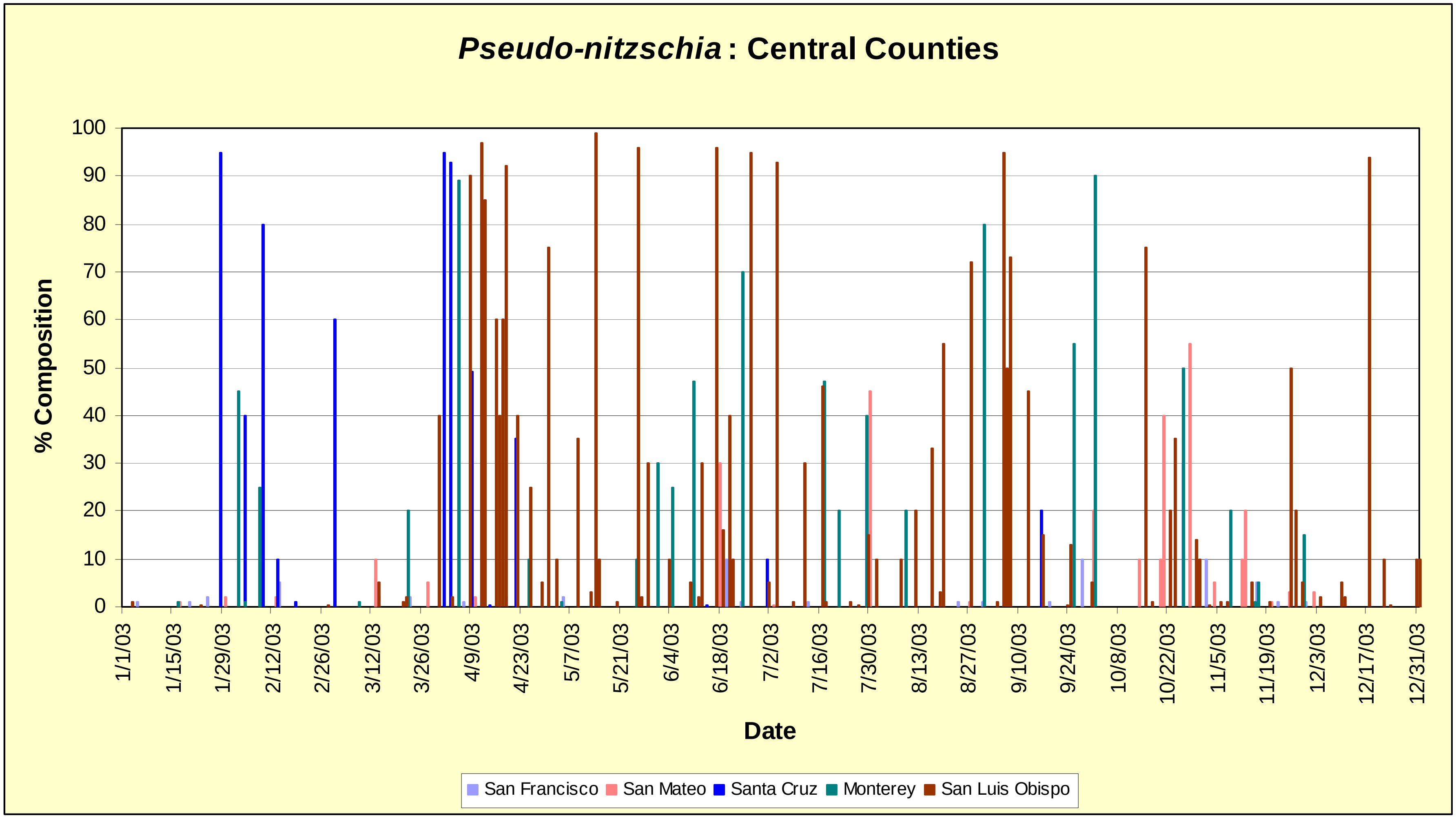

Figure 10. Temporal distribution and percent composition of *Pseudo-nitzschia spp.* (southern counties).

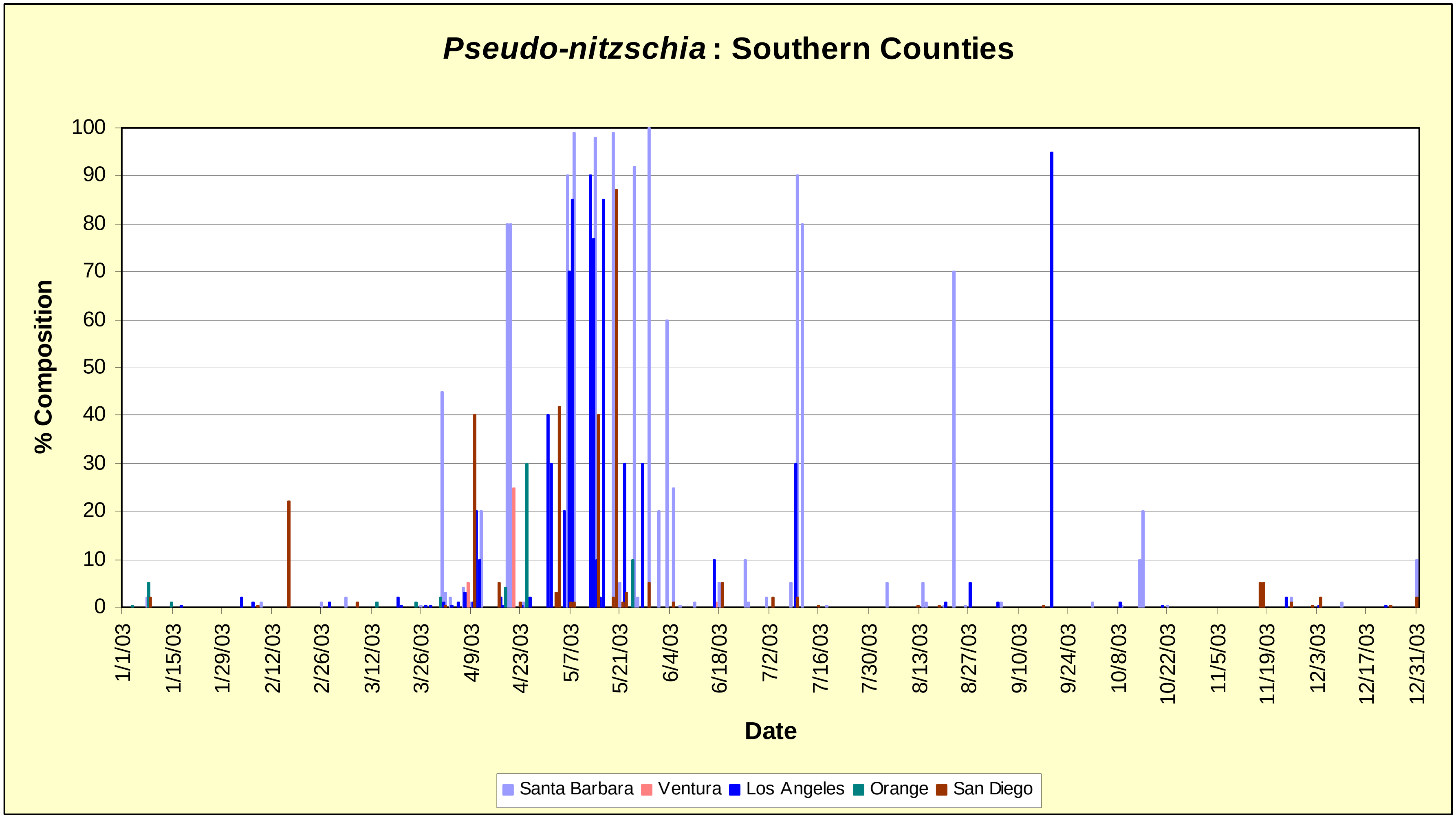

Figure 11. Temporal distribution and relative abundance index of *Pseudo-nitzschia spp.* (northern counties).

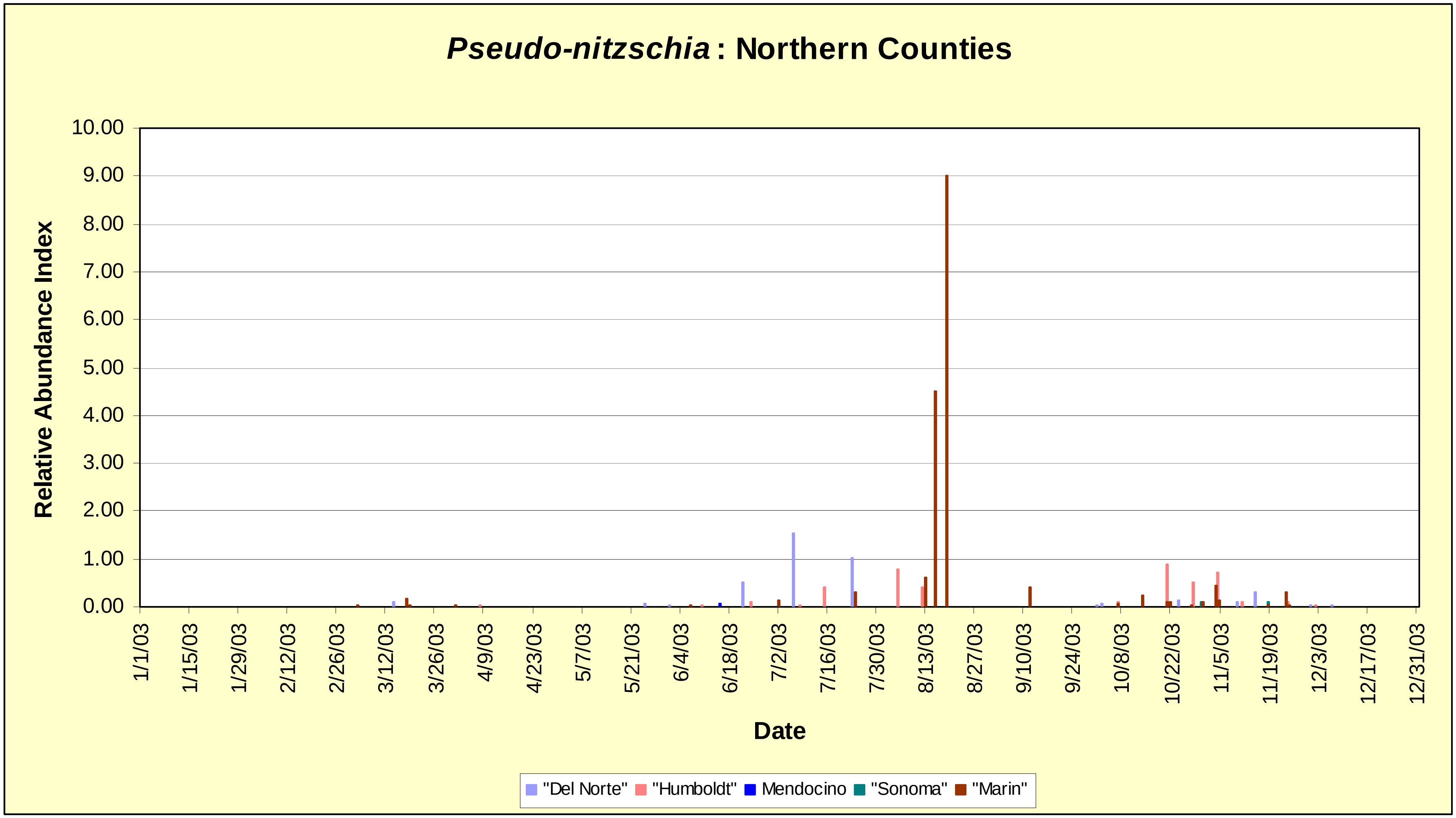

Figure 12. Temporal distribution and relative abundance index of *Pseudo-nitzschia spp.* (central counties).

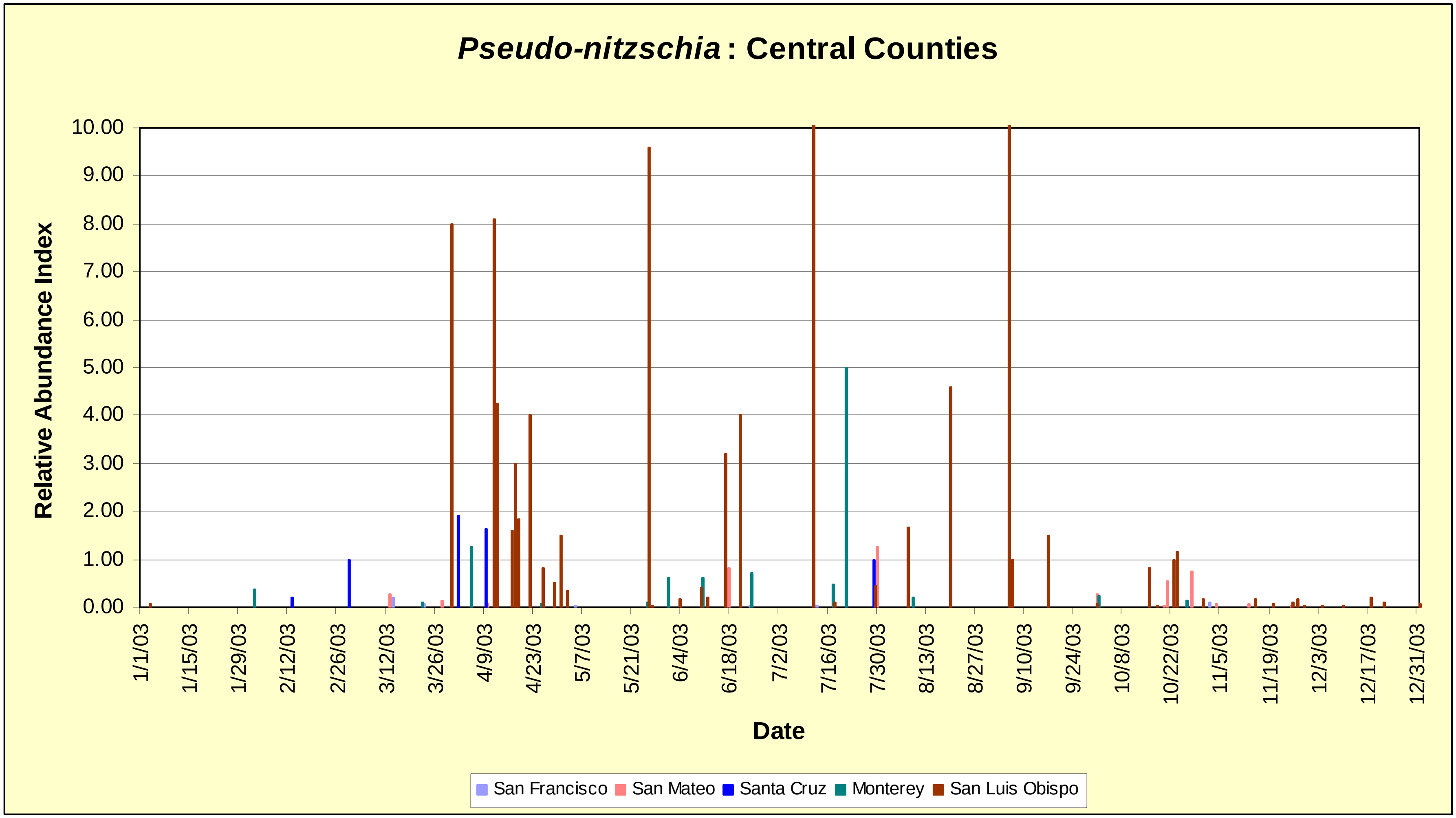

Figure 13. Temporal distribution and relative abundance index of *Pseudo-nitzschia spp.* (southern counties).